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Frar Ali, Doctor of Engineering, Professor (University of Batna, Algéria), **Herasymov Henrikh, Candidate of Engineering, Associate Professor** (National University of Water Management and Nature Resources Use, Rivne), **Hafied Yacine, Post-graduate Student** (University of Batna, Algéria)

THE INFLUENCE OF TURBINE SHUTDOWN STATE IN A HYDROPOWER STATION ON THE INITIALS VALUES OF WATER HAMMER WITH THE METHOD OF BERGERON

The studies of changes in values hammer, compared to its initial values, are a real problem for researchers hydraulics, due to complex and multi parameters that come into play, in this work we will put the fingers on a specific phenomenon operation of hydropower stations, reflecting the case of a simultaneous stopping of a turbine (valve) or other turbines are shut down for technical reasons or exploitation slump to meet a minimum requirement requiring the operation of a turbine to regulate the storage of water, the consequences resulting from such operations result in changes to local pressures and flows in the system considered, to understand the problem we will analyze with the method of Bergeron.
Keywords: water hammer, hydropower station, method of Bergeron.

INTRODUCTION:

Generators are the main hydroelectric energy source on the network, faults can occur on the hydraulic or the generator itself, optimal operation is expected to master as soon as possible all faults related to the operating system and water hammer that can be caused extensive damage. It poses a very important for researchers, especially in branched networks. This article will discuss a case of well-defined phenomenon which is the study of variations in pressure and flow

PROBLEM:

The influence of turbine shutdown state in a hydropower station on the initial values of the hammer, in a system where a single turbine in operation, this problem specific to the operation of hydropower stations, reflecting the case a simultaneous shutdown of one or more turbines for technical reasons or exploitation slump to meet a minimum requirement requiring the operation of a turbine to regulate the water storage Designed for drinking water that for irrigation, the consequences resulting from such operations result in changes to local pressures and flows in the system under consideration:

The calculation of the variation of pressure and flow is through the graphical method Bergeron.

CALCULATION HYPOTHESES:

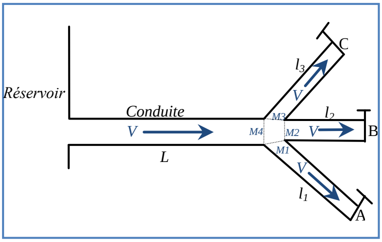

Fig. 1. Schéma 01

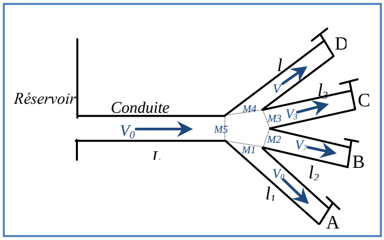

Fig. 2. Schéma 02

Assumption of the proposed system:

1. The losses are zero.
2. The lengths of secondary pipes identical.
3. Sections of the secondary lines are identical.
4. The angular coefficients of the secondary pipes are equal.
5. The length of the main pipe extremely large compared to the secondary pipes.
6. The slopes of the pipes are zero.

CALCULATION OF DATA:

Initial conditions $Q_0=5$ and $H = H_O$

$$a = \tan \alpha = (c / g.S)$$

With:

a: slope of the main duct

S: section of the main pipe;

c: the speed waveform in the main duct;

g: acceleration of gravity;

$$a_1 = a_2 = a_3 = a_4 = \alpha_1 = tg\,(c_1/g.S_1);$$

a_1, a_2, a_3 and a_4: angular coefficients of secondary lines A, B, C and D successively (in all proposed schemes).

S_1, S_2, S_3 and S_4: secondary pipes sections A, B, C and D successively (in all proposed schemes).

c_1, c_2, c_3 and c_4: wave velocities in the secondary lines A, B, C and D successively (in all proposed schemes).

DEFINITION OF THE METHOD:

Bergeron method allows to determine the hydraulic pressure variations and flow due to water hammer without explaining analytically the nature of the wave. We develop below the graphical method has the merit of being very simple when you understand the construction mechanism.

CONSTRUCTION CHART:

To begin construction of the blueprint, you must know:

a) the initial direction of the flow before the disturbance;

b) the point and time of departure of the observer, that is to say, Q_0, H_0 and t_0.

c) the direction of travel of the observer in order to conduct draw the line of Bergeron after the starting point.

d) characteristic of the device at the other end of the pipe at time $t_1 = t_0 + L / c$. In other words, we must build, at time $t = t_1$, the curve H = f (Q) of the device (tank, turbine) that meet the observer when he arrives at the end of the line.

To avoid errors in the construction graph, we often mark the point of intersection with a number and a letter directly representative of the transit time of the observer and the device it encounters. The unit of time used is in principle $\theta = 2l / c$ and origin of the disturbance is denoted by $\theta = 0$.

<u>APPLIQUATION OF THE METHOD OF BERGERON:</u>

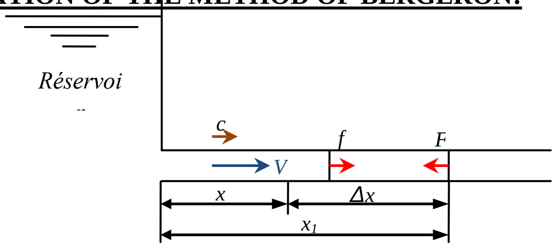

Fig. 3. Propagation of the pressure waves F and f

Consider the system of Fig. 3:

A main line length (l) and a flow rate (Q_0), the ends: upstream, it is connected to a reservoir (R) and downstream, a junction at the point M, a line (M_A) and (M_B) which the lengths of these lines ($l_1 = l_2$) and ($l \gg l_{1,} l_2$), the downstream ends of the two pipes, turbines exist.

At point A, the initial state, the turbine is always open ($q_A = Q_0$)

At point B, the initial state, the turbine is still closed ($q_B = {}_0$)

Assuming the slopes of the lines (main, A and B) I = 0 is zero, and the losses are negligible.

At t = 0, the turbine at point A is closed abruptly.

CONDUCT A:

Observer from M at time $t = 0.5\theta$ with a velocity (speed of the wave line A) where the flow starts to vary where M (H = H0 and q = Q_0), in a wave A f and arrived at the moment 1θ (point A1) it returns to M with the same speed always next wave F, M and arrives at the moment 1.5θ (point $M_{0.5}$) it back to A along a wave f (point A_2) amounts to M at the instant 2.5θ (point $M_{1.5}$) and so on.

LINE B:

The second observer from B at the instant t = θ with a velocity (speed of the wave B of the pipe), the flow begins to change when B (H = H_0 and q = 0), in a wave F and M arrived at the moment 1.5θ (point $M_{1.5}$) it returns to M with the same speed always next wave f, and reaches B in earnest 2θ (point B_2), he returned to M following a wave f (point $M_{2.5}$) returns to B at the moment 2.5θ and so

From the third observer.

WATERMAIN:

R at time t = θ. with a speed (speed of the wave of the main pipe) in the flow begins to vary where M (H = H_0 and q = Q_0), the observer does not return as the main duct is long enough.

GRAPHIC consruction:

1. DIAGRAM N ° 01 (n = 3):

1.1. a = 1; a2 a1 = 3 = 3;

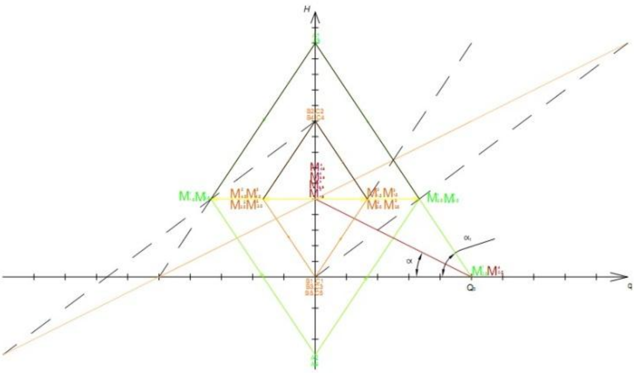

Fig. 4. Graphical construction method by Bergeron

Table 01: the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite principale	
	H	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**
1	15,00	0,00	0,00	0,00	-	0,00		
1,5	5,00	-3,33	5,00	1,67	5,00	1,67	5,00	0,00
2	- 5,00	0,00	10,00	0,00	10,00	0,00		
2,5	5,00	3,33	5,00	-1,67	5,00	- 1,67	5,00	0,00
3	15,00	0,00	0,00	0,00	0,00	0,00		
3,5	5,0000	-3,33	5,00	1,67	5,00	1,67	5,00	0,00
4	-5,00	0,00	10,00	0,00	10,00	0,00		
4,5	5,00	3,33	5,00	-1,67	5,00	-1,67	5,00	0,00
5	15,00	0,00	0,00	0,00	0,00	0,00		

1. *$a=1$; $a_1=2$; $a_2=2$:*

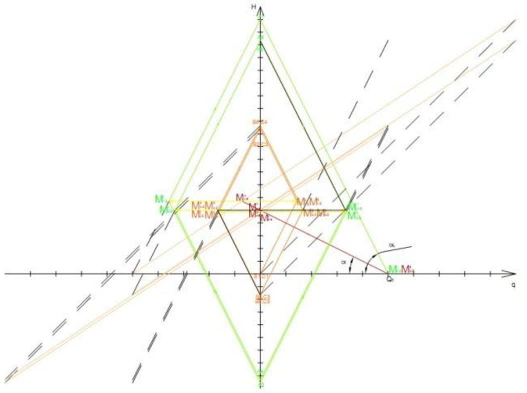

Fig. 5. Graphical construction method by Bergeron

Table N°02 : the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite principale	
	H	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**
1	10,00	0,00	0,00	0,00	-	0,00		
1,5	4,00	- 3,00	4,00	2,00	4,00	2,00	4,00	1,00
2	- 2,00	0,00	8,00	0,00	8,00	0,00		
2,5	4,80	3,40	4,80	- 1,60	4,80	- 1,60	4,80	0,20
3	11,60	0,00	1,60	0,00	1,60	0,00		
3,5	4,96	- 3,32	4,96	1,68	4,96	1,68	4,96	0,04
4	-1,68	0,00	8,32	0,00	8,32	0,00		
4,5	4,99	3,334	4,99	- 1,66	4,99	- 1,66	4,99	0,01
5	11,66	0,00	1,66	0,00	1,66	0,00		

2. ***a=1 ; a_1=4 ; a_2=4:***

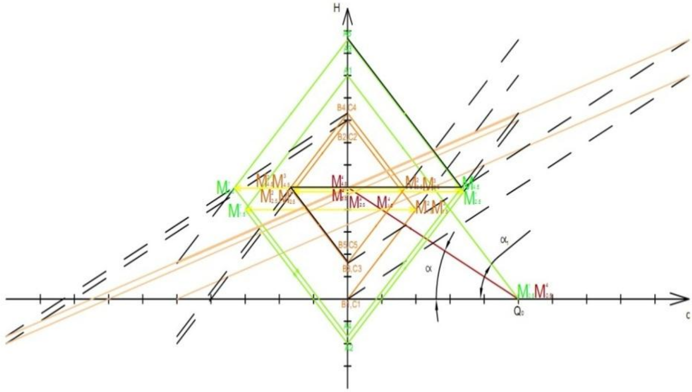

Fig. 6. Construction graphique par la méthode Bergeron

Table N°03 : the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite principale	
	H	Q	H	Q	H	Q	H	Q
1	15,00	0,00	0,00	0,00	0.00	0,00		
1,5	5,00	-3,33	5,00	1,67	5,00	1,67	5,00	0,00
2	- 5,00	0,00	10,00	0,00	10,00	0,00		
2,5	5,00	3,33	5,00	-1,67	5,00	-1,67	5,00	0,00
3	15,00	0,00	0,00	0,00	0,00	0,00		
3,5	5,00	-3,33	5,00	1,67	5,00	1,67	5,00	0,00
4	- 5,00	0,00	10,00	0,00	10,00	0,00		
4,5	5,00	3,33	5,00	-1,67	5,00	- 1,67	5,00	0,00
5	15,00	0,00	0,00	0,00	0,00	0,00		

1. **SCHEMAS N°02 (n=4) :**

1.1. ***a=1 ; a_1=4 ; a_2=4:***

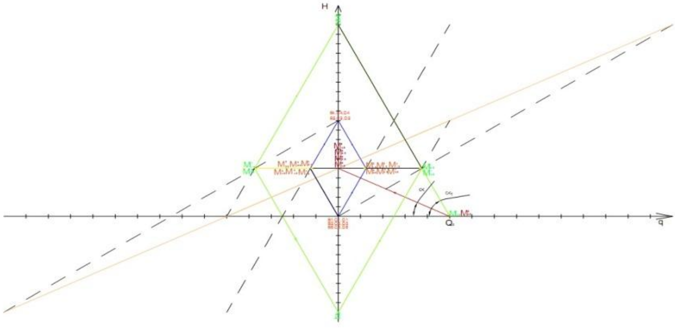

Fig. 7. Graphical construction method by Bergeron

Table N°04 : the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite D		Conduite principale	
	H	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**
1	16,00	0,00	0,00	0,00	-	0,00	-	0,00		
1,5	4,00	-3,00	4,00	1,00	4,00	1,00	4,00	1,00	4,00	0,00
2	-8,00	0,00	8,00	0,00	8,00	0,00	8,00	0,00		
2,5	4,00	3,00	4,00	-1,00	4,00	-1,00	4,00	-1,00	4,00	0,00
3	16,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
3,5	4,00	-3,00	4,00	1,00	4,00	1,00	4,00	1,00	4,00	0,00
4	-8,00	0,00	8,00	0,00	8,00	0,00	8,00	0,00		
4,5	4,00	3,00	4,00	-1,00	4,00	-1,00	4,00	-1,00	4,00	0,00
5	16,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		

1.2. $a=1$; $a_1=3$; $a_2=3$:

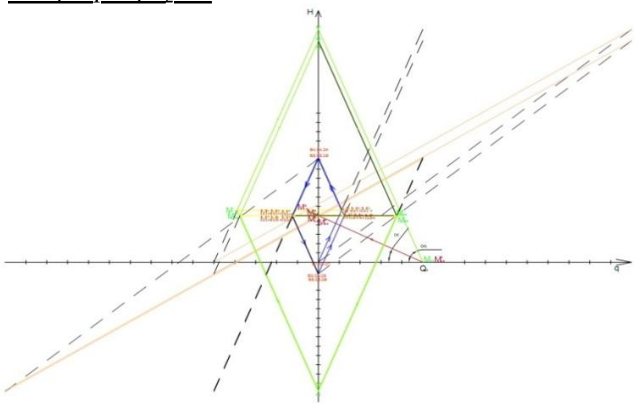

Fig. 8. Graphical construction method by Bergeron

Table N°05 : the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite D		Conduite principale	
	H	Q	H	Q	H	Q	H	Q	H	Q
1	12,00	0,0000	0,00	0,00	-	0,00	-	0,00		
1,5	3,49	-2,86	3,49	1,15	3,43	1,14	3,49	1,146	3,43	0,57
2	-5,14	0,00	6,86	0,00	6,86	0,00	6,86	0,006		
2,5	3,92	3,02	3,92	-0,98	3,92	-0,98	3,92	-1.00	3,92	0,08
3	12,98	0,00	0,98	0,00	0,98	0,00	1.00	0,00		
3,5	3,99	-3.00	3,99	1,00	4.00	1,00	4.00	1,00	4.00	0,01
4	-5,00	0,00	7.00	0,00	7.00	0,00	7.00	0,00		
4,5	4.00	3,00	4.00	- 0,99	4.00	-1.00	4.00	- 1.00	4.00	0,00
5	13.00	0,00	1.00	0,00	1.00	0,00	1.00	0,00		

1.3. $a=1$; $a_1=5$; $a_2=5$:

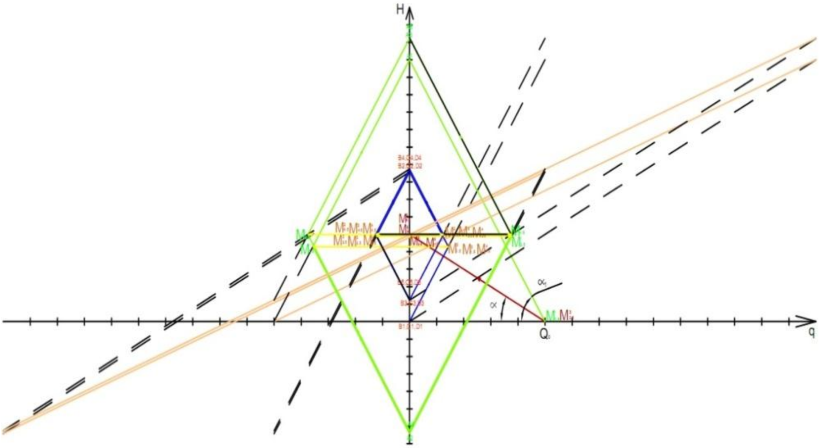

Fig. VIII. Graphical construction method by Bergeron

Table N°06 : the results obtained

Temps t (θ)	Conduite A		Conduite B		Conduite C		Conduite D		Conduite principale	
	H	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**	**H**	**Q**
1	20,00	0,00	0,00	0,00	-	0,00	-	0,00		
1,5	4,44	- 3,11	4,44	0,89	4,44	0,89	4,44	1.00	4,44	-0,44
2	- 11,11	0,00	8,89	0,00	8,89	0,01	8,89	0,00		
2,5	3,95	3,01	3,95	-0,99	3,95	- 0,99	3,95	-0,99	3,95	0,05
3	19,01	0,00	-0,99	0,00	-0,99	0,00	-0,99	0,00		
3,5	4,00	- 3,00	4,01	1.00	4,00	1.00	4,01	1.00	4,00	0,00
4	- 11,00	0,00	9.00	0,00	9.00	0,00	9.00	0,00		
4,5	4.00	3,00	4.00	- 1.00	4.00	- 1.00	4.00	- 1.00	4.00	0,00
5	19,00	0,00	-1.00	0,00	-1.00	0,00	-1.00	0,00		

CONCLUSION:

Following the results obtained it can be deduced graphically a relationship between the change in pressure and flow for different values of "n", as a function of time:

$$\Delta H_{t+\Delta t} = \left(a + a_1 / n\right) Q_{n+1} (1,5) \quad (8)$$

With:

$\Delta H_{t+\Delta t}$: The change of pressure (load) as a function of time.

a_1: the angular coefficient of the secondary pipe.

a: the slope of the main pipe.

n: number of laterals.

$Q_{n+1}(1,5)$: The change in flow rate over time.

This equation can be used to find out the amount of change of the load in each line.The application of the graphic method Bergeron gave the results values of pressure variations and flows in the proposed systems

Following the analysis of the results, we note the following points:

1. In the case where the number of branching (n) is equal to the angular coefficient of the secondary pipes (a_1 = n), it was found that there is a conservation of the initial values of pressure surges in the different time intervals, c . A.D. values of pressure and flow remained stable baseline (Δ H=0).

2. In the case where the number of branching (n) is greater than the angular coefficient of secondary lines (n> a_1), it was found that there is a variation in pressure and flow compared to baseline, this variation continues until 'that the system is an equilibrium state at time t = 4.5θ.

Pressures in the pipe ends (points A, B, C and D) to increase when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the flow amount zero.

3. In the case where the number of branching (n) is less than the angular coefficient of the secondary pipes (n <a_1), it was found that there is always a change of flow and pressure relative to the initial values, the variation continues to which the system takes its equilibrium state ie when the value of the main duct flow approaches nearer and nearer the flow amount zero.

a. Pressures in the ends of the pipe at point A to decrease when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the value of the zero flow, the pressure decreases from an initial value ((A_1 = (c_1 / g) Vo) to a value A_5= ((c_1/g) Vo- Δ H).

Pressures in the pipe ends (points B, C and D) to increase when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the value of the zero flow, the pressure rises from an initial value ((B_1 = (c_2 / g) Vo) to a value B5= ((c_2/g) Vo+ Δ H).

b. The pressures in the point (M), ie the branch point, vary with alternating (larger value to a smaller value), this variation is continued until the flow rate is zero.

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Фрар Алі, д.т.н., професор (Університет Бетна, Алжир),
Герасимов Г. Г., к.т.н., доцент (Національний університет водного господарства та природокористування використання, м. Рівне),
Хафаїд Ясін, аспірант (Університет Бетна, Алжир)

АНАЛІЗ ВПЛИВУ ЗУПИНКИ ТУРБІНИ ГЕС НА ПАРАМЕТРИ ГІДРАВЛІЧНОГО УДАРУ МЕТОДОМ БЕРЖЕРОНА

Дослідження зміни значень параметрів гідравлічного удару в порівнянні з їх первісними значеннями являють собою реальну проблему для дослідників, оскільки гідравлічні параметри є комплексними і складними. Дана робота стосується специфічних явищ експлуатації гідроелектростанцій, які обумовлені одночасними зупинками турбін, в той час як решта турбін закриті з технічних причин або через експлуатаційний спад навантаження і з метою регулювання та зберігання води. В даній статті описані наслідки зміни режимів роботи обладнання в вигляді зміни місцевих тисків і потоків в системі. Ці та інші проблеми було проаналізовано за допомогою методу Бержерона.
Ключові слова: гідравлічний удар, гідроелектростанція, метод Бержерона.

Фрар Али, д.т.н., профессор (Университет Бэтна, Алжир),
Герасимов Г. Г., к.т.н., доцент (Национальный университет водного хозяйства и природопользования использования, г. Ровно),
Хафаид Ясин, аспирант (Университет Бэтна, Алжир)

АНАЛИЗ ВЛИЯНИЯ ОТКЛЮЧЕНИЯ ТУРБИНЫ ГЭС НА ПАРАМЕТРЫ ГИДРАВЛИЧЕСКОГО УДАРА МЕТОДОМ БЕРЖЕРОНА

Исследование изменения значений параметров гидравлического удара в сравнении с их первоначальными значениями, представляют собой реальную проблему для исследователей, поскольку гидравлические параметры являются комплексными и сложными. В данной работе затрагиваются специфические явления эксплуата-

ции гидроэлектростанций, которые обусловлены одновременными отключениями турбин (закрытиями затворов), в то время как остальные турбины закрыты по техническим причинам или из-за эксплуатационного спада нагрузки и в целях регулирования и сохранения воды. В данной статье описаны последствия изменения режимов работы оборудования в виде изменения местных давлений и потоков в системе. Эти и другие проблемы были проанализированы с помощью метода Бержерона.

Ключевые слова: гидравлический удар, гидроэлектростанция, метод Бержерона.